

# DETECTION OF UNEXPLODED ORDNANCE USING AIRBORNE LWIR EMISSIVITY SIGNATURES

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## ABSTRACT

This paper investigated the potential of using LWIR spectral emissivity signatures to detect unexploded ordnance in the impact ranges of the Canadian Forces Bases. The experimental setup was composed of inert projectiles of various sizes and coating, and various potential false alarm objects. LWIR Hypercam images were acquired at 30 minutes intervals between 9:30 on Aug 23 and 21h00 on Aug 24 2013 from a height of 20m at nadir. Images were processed to emissivity and the Generalized Likelihood Ratio Test (GLRT) was used to perform the detection. Results show that the GLRT is suitable for detecting the paint used to cover the projectiles if they are not covered by vegetation. Other detected targets, such as glass and wood, are spectrally distinct and would not appear as false alarms.

**Index Terms**— Hyperspectral, Long Wave Infrared, Emissivity, Target Detection

## 1. INTRODUCTION

Unexploded ordnance (UXO) can be found in impact ranges of Canadian Forces Bases (CFB) and may pose a risk to humans and to the environment because of the explosives, chemicals, and propellants they may contain. Unexploded ordnance removal on CFB is typically performed on a yearly basis in the springtime before the onset of vegetation growth. Removing all newly landed UXO each year would be the ideal solution to the contamination problem. New UXO still retain their paint while UXO that are left unattended for many years become coated with rust and undergo metal thinning that poses an increased risk of detonation. No single sensor can detect UXO in all possible conditions with no false alarms. Instead, a combination of different sensors provides the best approach [1, 2]. Current commonly used sensors consist primarily of geophysical sensors (ground probing radar, magnetometer, electromagnetic induction), and remote sensing sensors (reflective & emissive single band and multispectral;

reflective hyperspectral; radar). Because of previous successes using thermal infrared bands for UXO [3, 4] and landmine detection [5], this paper aims at exploring how measurements of long-wave (LWIR) spectral emissivity can contribute to the detection of UXO.

## 2. METHODOLOGY

### 2.1. Experimental setup

The experiment took place in a soil and grass background typical of the one found in the impact ranges of CFB Valcartier. A series of targets were positioned on the ground within a 12 m x 10 m grid composed of 2 m x 2 m cells (Figure 1). One-sided galvanized aluminum plates of 20 cm x 20 cm were used to mark the corner of the grid cells. The targets of interest consisted of inert projectiles of various sizes displayed in various conditions: exposed, covered or buried in background, painted or rusted. Other objects commonly found in training ranges were also included as sources of potential false alarms. They included materials made of rubber, cardboard, metal, wood, glass and plastic (Figure 1).

### 2.2. Laboratory LWIR signature measurements

Spectral signatures of several UXOs were measured under controlled conditions using a full-spectrum reflectometer (FSR), manufactured by ABB Bomem [6]. The FSR was used as a contact probe to measure the diffuse spectral reflectance of the UXO in the 7 to 13.5 micron range at a spectral resolution of 8 cm<sup>-1</sup>. An infra-gold plate was used as a reference. The signal-to-noise ratio of the measurement was about 500:1 for an acquisition time of 90 s.

### 2.3. Hyperspectral Data acquisition

Images were acquired at 30 minutes intervals between 9:30 on Aug 23 and 21h00 on Aug 24 2013 using a mid-wave infrared (MWIR) and a LWIR Telops Hypercam hyperspectral sensors mounted at a height of 20 m on a

boom lift producing a spatial resolution of 3 cm. Only the LWIR images acquired at 12h38 on Aug 23 were analyzed in this study.

## 2.4. Data processing and analysis

The DEFILTE technique using an infra-gold plate positioned in the image was used to extract the temperature and the emissivity of the image pixels [7]. A LWIR emissivity library was built using the FSR laboratory spectra and re-sampled to the LWIR Hypercam wavelengths (850 to 1225 wavenumber). The Generalized Likelihood Ratio Test (GLRT), also known as Scharf's GLRT [8], was used to perform the detection. This detector was uniformly most powerful (UMP) and had a constant false alarm rate (CFAR) output [9]. The detector can be written as:

$$T_{GLRT} = \frac{\mathbf{m}^T \mathbf{P}_B^+ \mathbf{m}}{\mathbf{m}^T \mathbf{P}_{BS}^+ \mathbf{m}}$$

where  $\mathbf{m}$  is the measured spectrum,  $\mathbf{P}_B^+$  is the projector out of the background subspace and  $\mathbf{P}_{BS}^+$  is the projector out of the background and signature subspace. For any set of background  $\mathbf{B}$

$$\mathbf{P}_B^+ = \mathbf{1} - \mathbf{B}(\mathbf{B}^T \mathbf{B})^{-1} \mathbf{B}^T$$

or

$$\mathbf{P}_B^+ = \mathbf{1} - \mathbf{U} \mathbf{U}^T$$

if  $\mathbf{U}$  is an orthonormal base of  $\mathbf{B}$ . The orthonormal base  $\mathbf{U}$  was calculated with the Singular Value Decomposition (SVD) [10], which results in a descending ordering of the basis vectors.

## 3. RESULTS

Figure 2 shows detection results for: (a) painted projectiles, (b) glass and (c) wood pieces. The upper row displays the pixels that were detected while the lower row displays the intensity of the detection. The painted projectiles are all detected except for the one in grid cell D1 (Figure 1) which is mostly covered by grass. The two painted metal cases located at the bottom of grid cell C5 and on the left of grid cell F4 are also detected. Rusted projectiles were not detected. Glass bottles, located between grid cells C2 and C3 and between grid cells F1 and F2 are also detected (Figure 5b). Three of the four wood pieces present in the

image are detected (Figure 5c). The one not detected is located between grid cells C5 and D5 and is partly covered by a metal rod. Figure 3 shows the good match of the measured emissivity signatures with the library signatures before and after background removal for the (a) painted projectiles, (b) the glass bottles and (c) the wood pieces.

## 4. CONCLUSION

This paper investigated the potential of using LWIR spectral emissivity signatures to detect unexploded ordnance. It was found that the GLRT is suitable for detecting the paint used to cover the projectiles if they are not covered by vegetation. Moreover, other detected targets (glass and wood) are spectrally distinct and would not appear as false alarms. The measurement of LWIR spectral emissivity has the potential for detecting new UXO with paint from an airborne survey. The next steps of this study will be to analyze: (1) the LWIR spectral emissivity over another similar experimental site in a soil background with no vegetation, (2) the MWIR Hypercam images, and (3) the temperature images extracted from both the LWIR and MWIR images. Finally, a multi-altitude airborne survey will also be performed over the impact ranges using the two Hypercams.

## 5. REFERENCES

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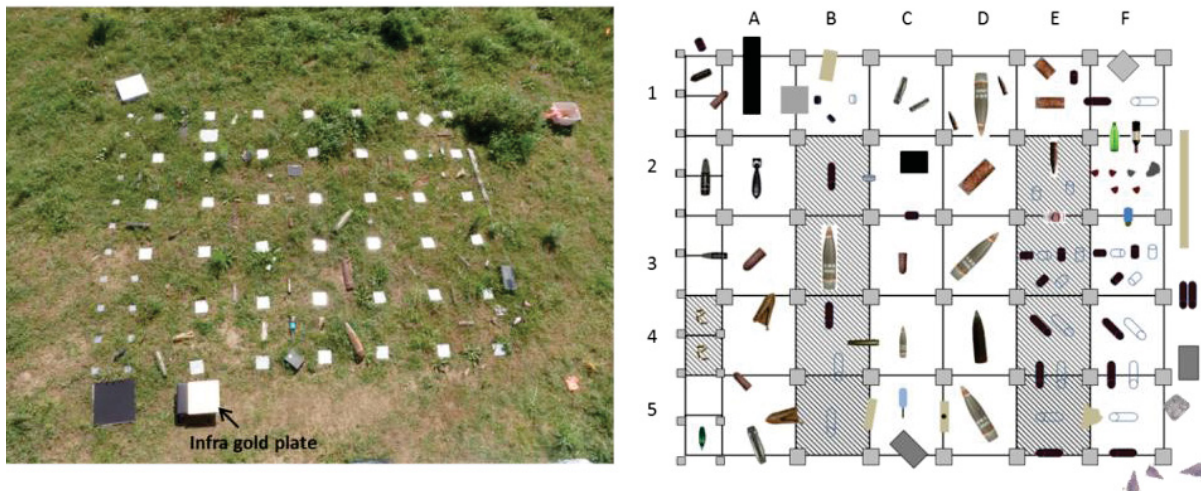


Figure 1. Ground target layout. Left: field of view of the Hypercams showing the cell grid bounded by the AI markers. Right: diagram of the target layout with labeled grid cells.

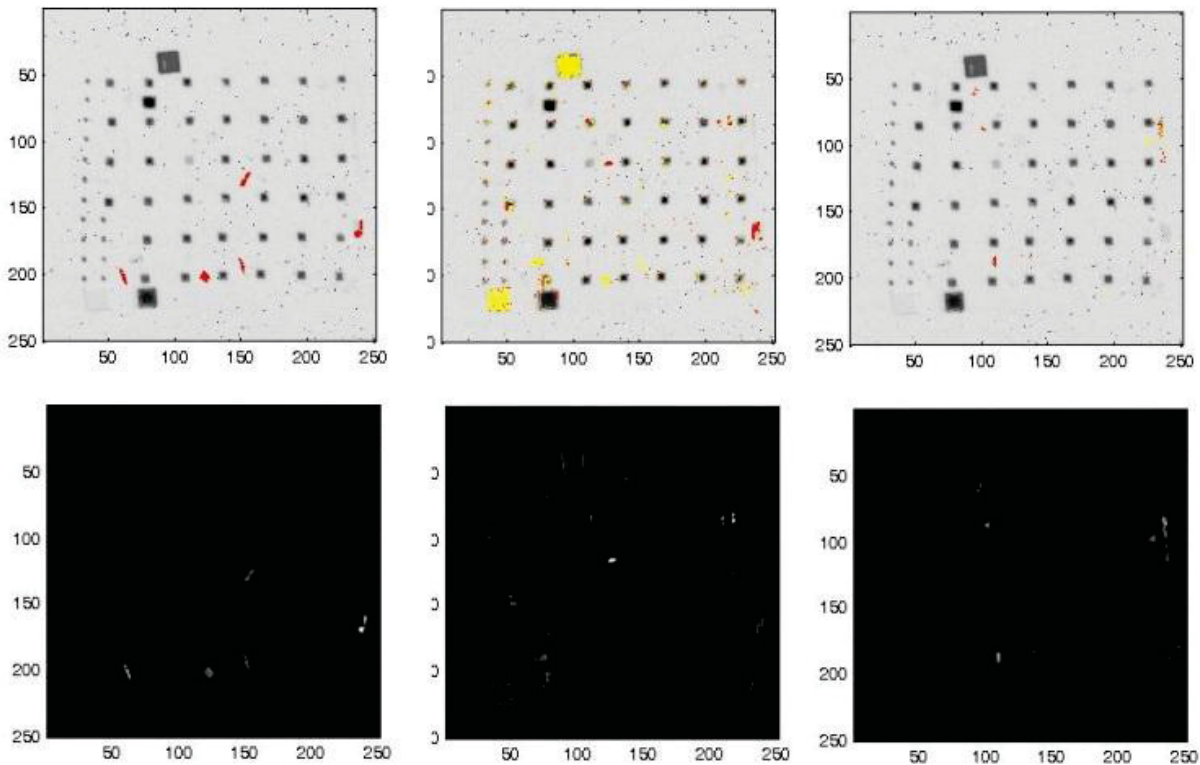


Figure 2. GLRT detection (upper row) and intensity (lower row) for (a) painted projectiles, (b) glass and (c) wood pieces.

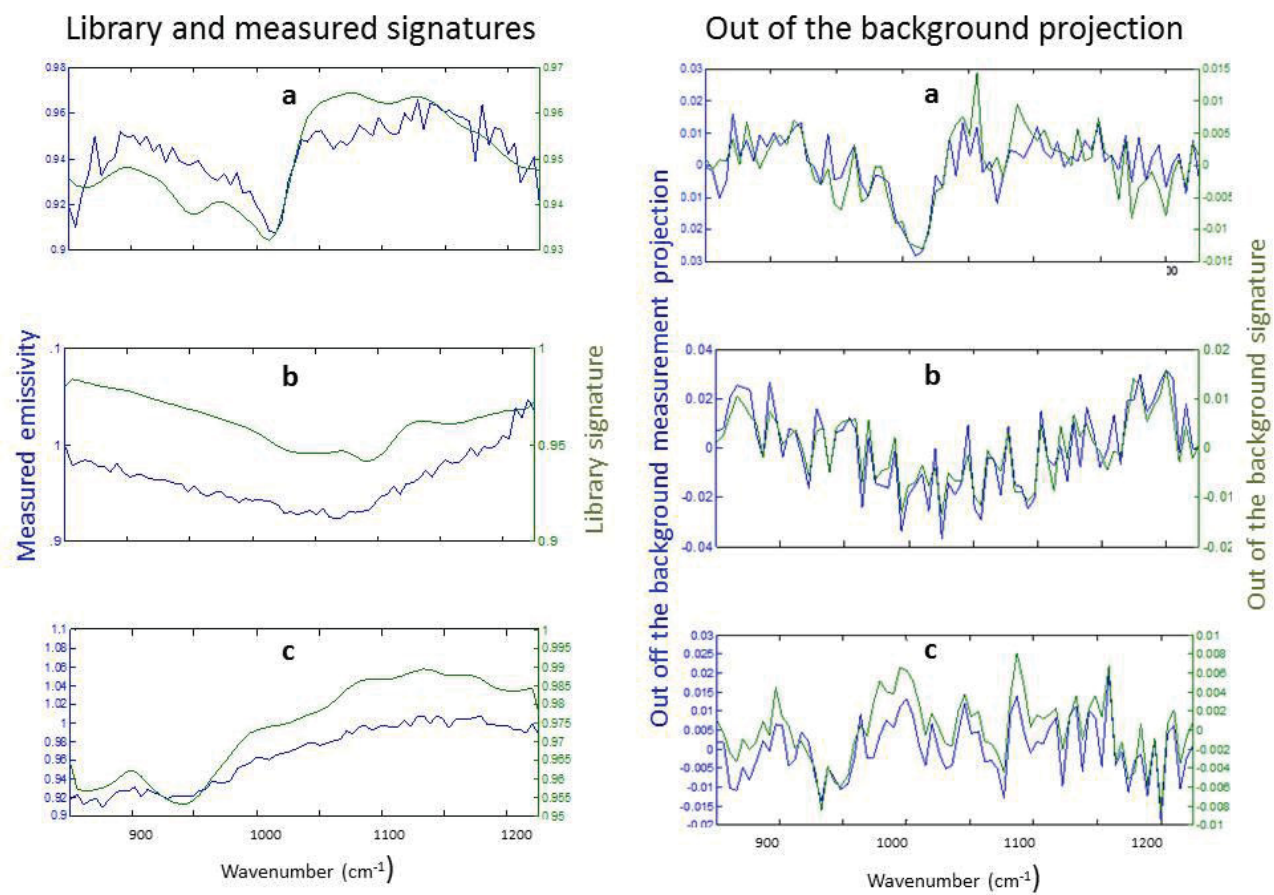


Figure 3. Library emissivity (green) and measured emissivity signatures (1<sup>st</sup> column) and out of the background projection